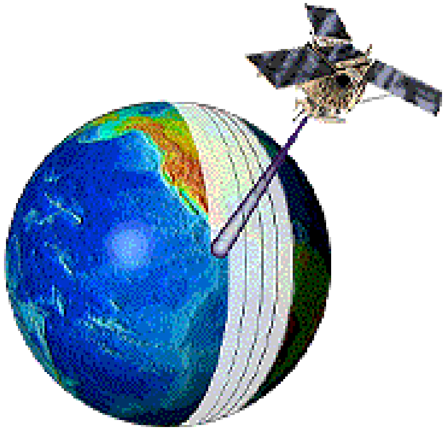
Using Satellite Data to Improve Ozone, PM and Visibility Modeling


NASA/TOMS

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Participating Institutions

- Lawrence Berkeley National Laboratory
- University of California, Berkeley
- Western States Petroleum Association

Research Team

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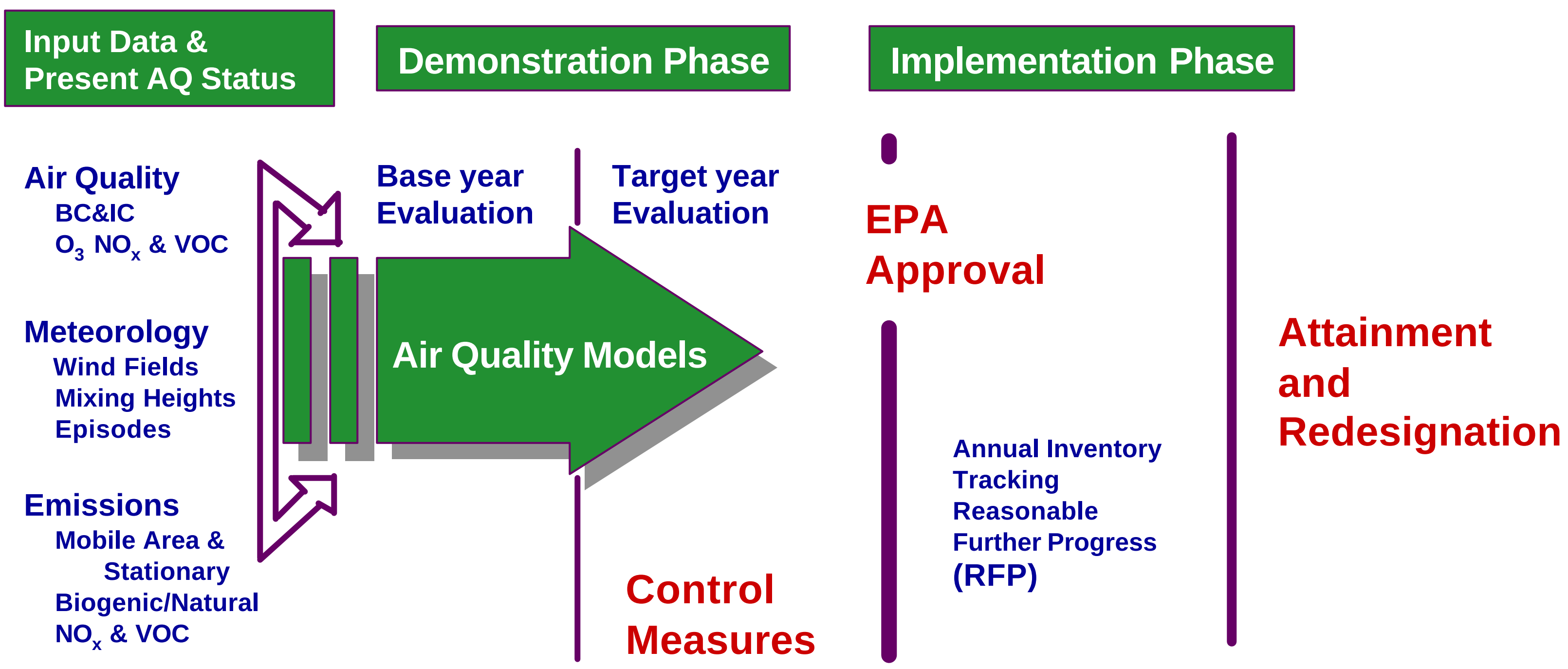
Research Objectives

- To use data collected by remote sensing from satellites combined with limited ground truth experiments to characterize the variability of actinic flux.
- To develop methods to incorporate descriptions of the variability into air quality modeling systems.
- Represent variability as a function of spatial location and time in air quality models

Clean Air Act (1990) makes modeling a cornerstone of air quality



Achieving Objectives Will

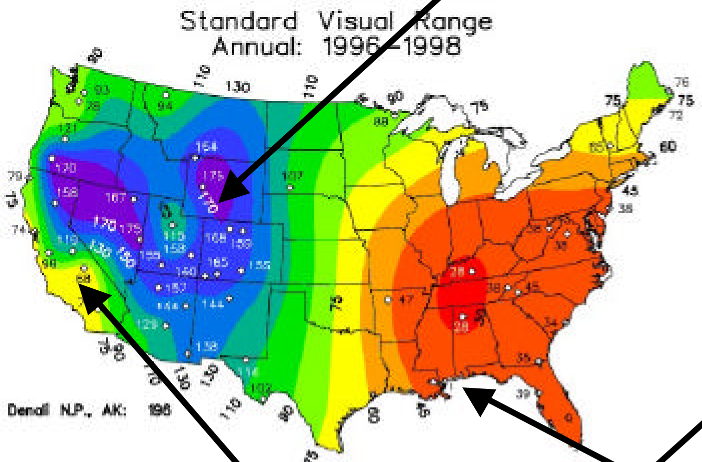
- **Substantially improve models and allow understanding how regional control options change with space and time for the**
  - **1-hour 120 ppm ozone standard**
  - **New 8-hour average 80 ppm ozone standard**
  - **New standards for PM-2.5**
  - **Regional haze rule**
  - **Risk-based standards for Hazardous Air Pollutants (HAPs)**

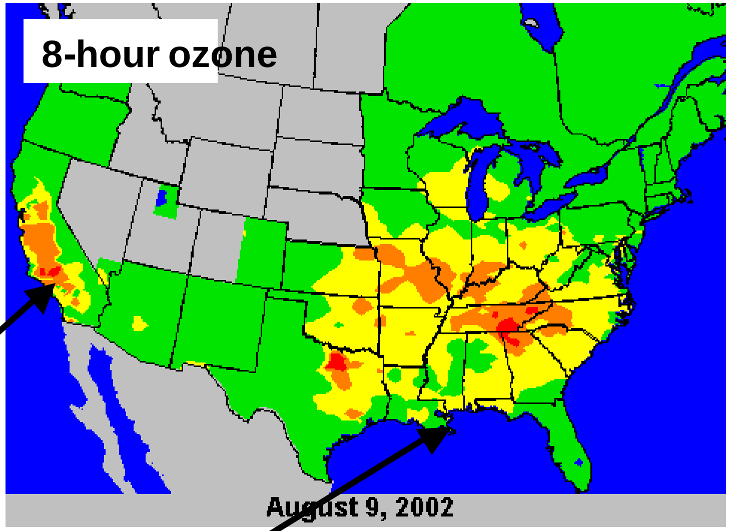
E&P and Air Quality

Regional Haze And Visibility

Central Rocky Mountain Region

Ozone





(yellow = 80 ppb)

Kern County
(also PM-2.5)

Gulf of Mexico/
Breton Island
(also PM2.5)

Consequence to Industry

Implementation of current and new standards, newly proposed rules, and new considerations of inter-basin and –state transport threaten to impose further control measures on E&P operations to reduce emissions.

This will impact production by limiting current operations and the permitting of new ones.

Variability in Atmospheric Processes

- Is responsible for differences among episodes
- Often restricts what we can model both with respect to spatial extent and temporal resolution
- Important yet expensive to characterize
  - (Satellite data will help considerably)
- Resulted in practice of monitoring and modeling 2 to 4 day air quality episodes that may not be representative

Benefit to Industry: Research will change existing practice-

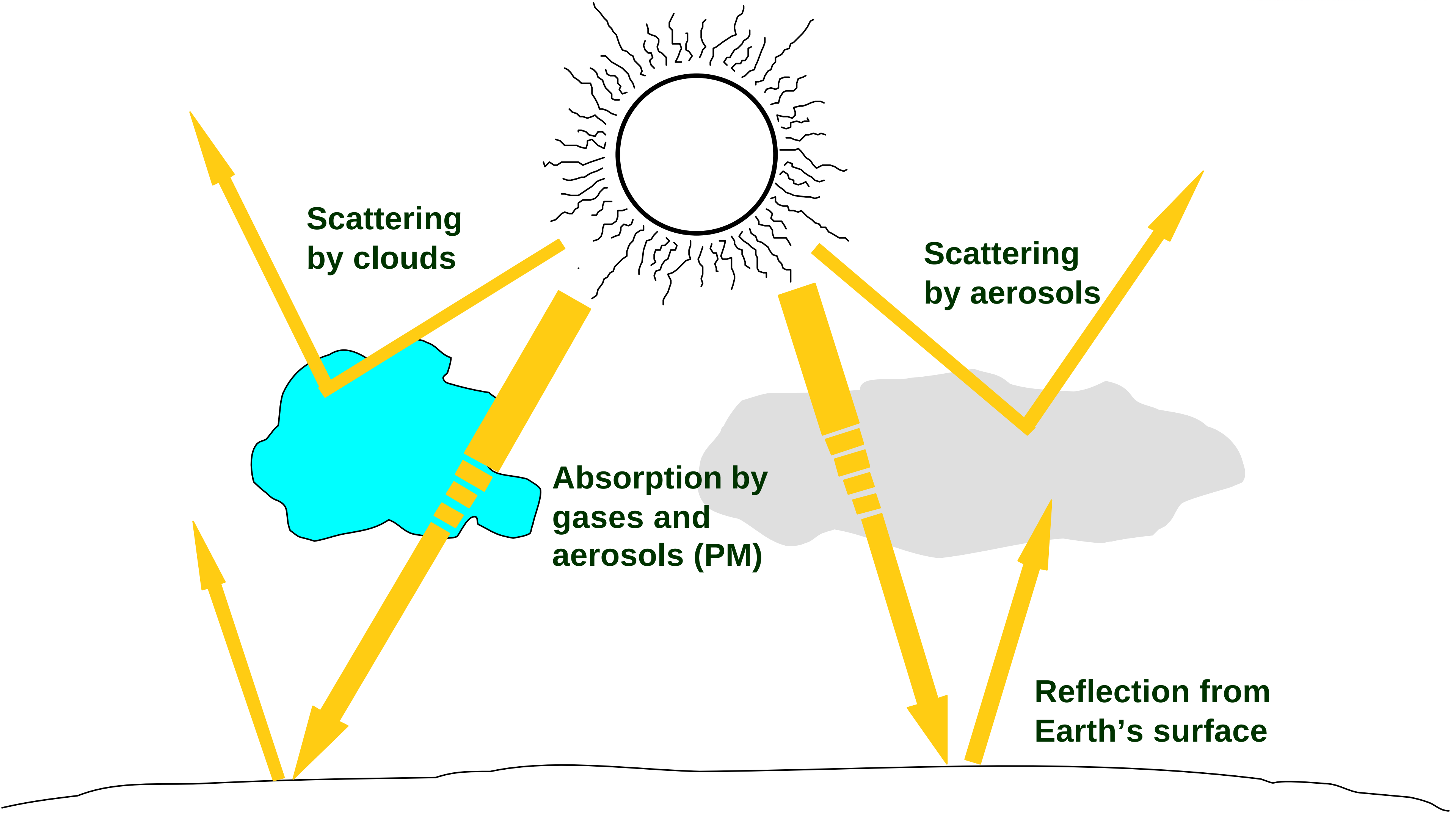
- Satellite measurements are especially suited for characterizing variability
  - ? Global coverage
  - ? Long term records
  - ? Spatial and temporal resolution
  - ? Ground truthing networks
- Will allow departure from modeling limited episodes so that seasonal modeling might be pursued so that

Control strategies that address many episodes can be devised

Why Actinic Flux?

- **Actinic flux: Amount of solar radiation reaching earth's surface per unit time per unit wavelength units: photons cm^{-2}s^{-1}nm^{-1}.**
- **Actinic flux:**
  - **drives the photochemistry**
  - **determines amount of light in a sight path**
  - **heats the atmosphere and surface etc.**
  - **IS HIGHLY VARIABLE**

Atmospheric interactions important for solar radiation



Causes of Actinic Flux Variability

- **Well understood:**
  solar zenith angle, terrain elevation
- **Moderately understood:**
  ground albedo, total ozone column
- **Poorly understood:**
  aerosol amount and optical properties
- **Most poorly understood:**
  clouds

Effects of these are often represented by changes in optical depth which is a measure of the opacity of the atmosphere to light.

How variable is the flux?

- Clouds can change opacity by a factor of 2 or more for ? in range 290-420 nm in 30 minutes
- Total column ozone can change by 10 %
  - (15 % and 4% in $O_3$and H_2CO photolysis)
- Aerosol optical depths can vary by factors of 5 within a few days
  - (25 % and 50 % in NO_2 and O_3 photolysis)
- Important aerosol optical properties can vary by 20 %--10 % error in photolysis and large error in visibility
- Error in NO_2 and O_3 photolysis translates almost 1:1 as predicted ozone, oxidant , and PM error

Initial Research Focus

- Determine impact of clouds, aerosols, and ozone on actinic flux in 290 to 420 nm region will yield following model improvements:
  - ? NO_2 photolysis rate —most important for predicting ozone
  - ? O_3 photolysis rate-important for predicting secondary PM production and predicting visibility
  - ? H_2CO photolysis rate—it affects OH concentration and H_2CO is a HAP carcinogen

Research Strategy

- **Step I**--Use data from the few satellites that measure a given spot with many instruments – (tend to have low spatial and temporal resolution) along with the inverse modeling algorithms that have been developed for their products to develop models for actinic flux attenuation.
- **Step II**--Correlate the output of these models with highly spatially and temporally resolved (but limited in number) satellite products to achieve a representation of the actinic flux variability on spatial and temporal scales of interest.

Research Strategy cont'd

- Step III-- Validate the model representation of variability with ground based measurements.
- Step IV-- Represent actinic flux variability in the EPA Community Multiscale Air Quality model for ozone, PM and visibility modeling

Satellite Data classification Scheme

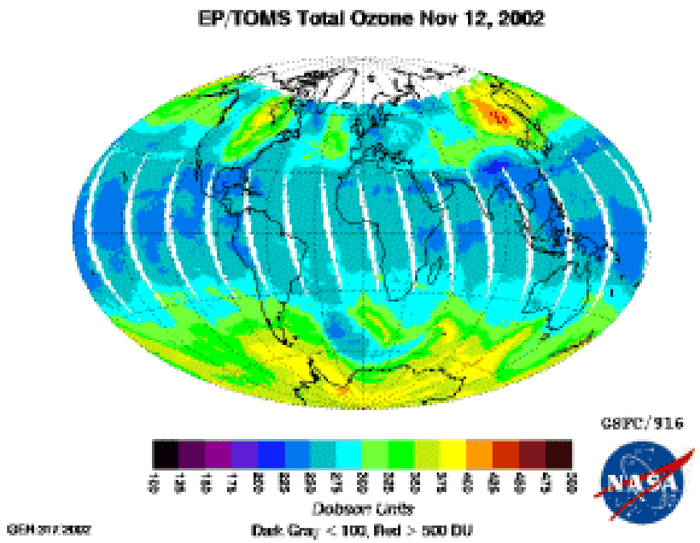
- Level 0: Raw data stream from spacecraft
- Level 1: Measured radiances, geometrically and radiometrically calibrated
- Level 2: Geophysical variables at highest resolution available
- Level 3: Averaged data providing spatially and uniform coverage—must choose a grid
- Level 4: Data produced by theoretical model, possible with measurement as input

Tools to Accomplish Research

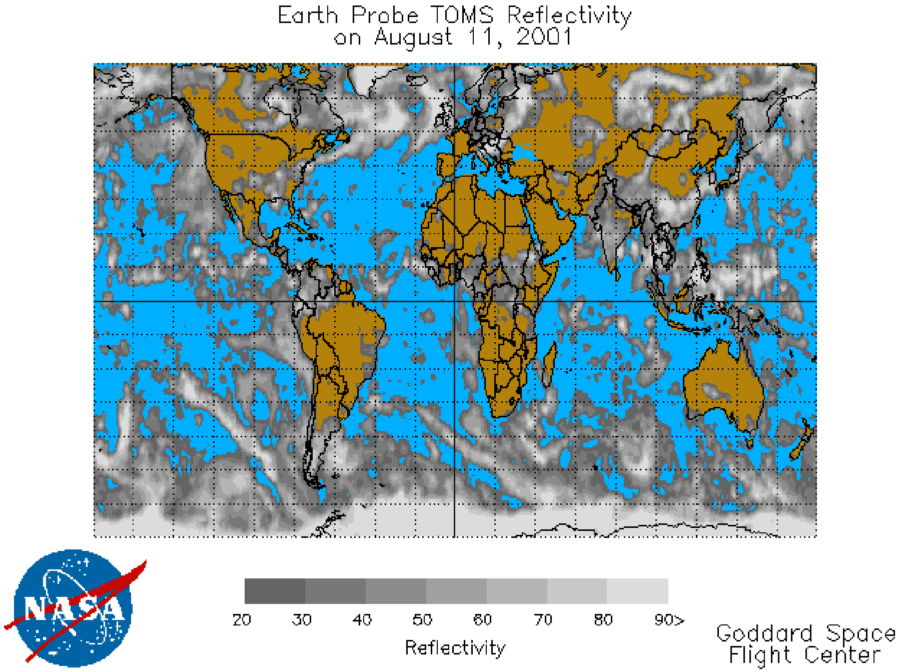
- **Total Ozone Monitoring Spectrometer (TOMS)**
  - ? Spacecraft: Earth Probe, Meteor 3, Nimbus 7, Triana, OMI etc.
  - ? Satellite products: aerosols, ozone, reflectivity, erythemal UV
- **NOAA Geostationary Operational Environmental Satellite (GOES)— many spacecraft**
  - ? Products: 5 imager bands and 19 sounder channels for water vapor, temperature, clouds etc
- **MODIS, MISR, and CERES**
  - ? Products: many spectral bands that provide considerable information about aerosols and clouds

TOMS Products

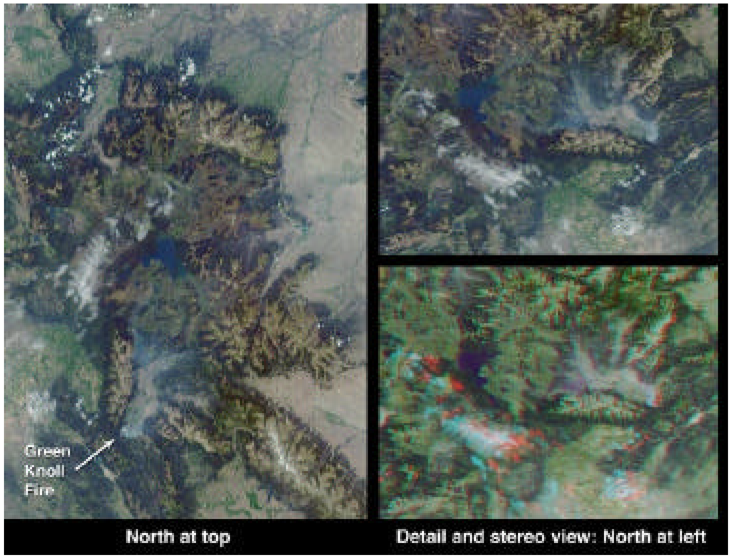
Total Ozone



Reflectivity



New NASA Aerosol Satellite Products



MISR: Aerosol image of fires in the Grand Tetons National Park, Wyoming

MISR: Aerosol image of the Louisiana/Mississippi Coast including the Breton Island Wildlife Refuge

Tools to Accomplish Research

- Algorithms developed by our group for optical depth calculations
- Algorithms developed by remote sensing community for ozone, aerosols, and clouds
- Ground truthing: USDA UV radiation monitoring sites data
  - Includes broadband meters to measure uv irradiance, temperature, humidity, and irradiance at 7 wavelengths in the visible
  - Other ground-based instruments (CCOS, Houston, Nashville, and other campigns

Tasks

- I Review and acquire data, algorithms, and scientific literature associated with ozone, clouds, and aerosols
- II Create web-based computer archive
- III Conduct analysis for prototype applications
  - Ozone and visibility emphasizing the photochemistry
- IV Technology transfer

Deliverables
(Within first 18 months)

- Bimonthly progress reports
- Year I report to DOE
- Paper at science meeting
- Paper submitted to journal
- Informing industry and regulators of progress
- Initial version web-based tool
  - Model input files for specific regions

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